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Status of the ALICE experiment

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Abstract. A status of the ALICE experiment is given. Details on the advancement of the major projects, together with results of recent performance tests are presented.

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1 Introduction

ALICE (A Large Ion Collider Experiment) is the experiment dedicated to the heavy-ion program at the LHC. The objective of this program [1] is to study nuclear matter in a regime where the temperature largely exceeds the critical temperature at which QCD predicts a transition toward the deconfined phase of freely moving quarks and gluons. The energy densities reached at LHC will, by far, surpass those attained at SPS and RHIC. This will thus provide the opportunity to explore the properties of nuclear matter at extremely high energy density and to study, in depth, the dynamics of the transition from deconfined matter toward ordinary hadronic matter. In parallel to the heavy-ion physics program, ALICE will exploit proton beams at LHC to collect comparison data and to pursue a dedicated p-p scientific program, complementary to the programs addressed by the ATLAS and CMS experiments.

To realize its scientific objectives, ALICE has elaborated a running scenario which has been endorsed [2] and discussed [3] at the recent LHC Performance Workshop. During the first year of operation ALICE will acquire valuable physics data in pp collisions and plans for an early physics pilot-run with lead beams, even at low luminosity. In a few days of running time, sufficient data can be collected to establish the global properties of the collision and to measure the observables with large cross-sections. During the second year, besides continuous data taking with the proton beams, ALICE will focus on the measurement of rare observables exploiting the lead beams at the nominal LHC luminosity ($\mathcal{L} \sim 10^{27}\mathrm{cm}^{-2}\mathrm{s}^{-1}$). During the third year, proton-, or alternatively deuteron- or alpha-, lead collisions will be studied to establish comparison data for heavy-ion collisions and to measure the nuclear modification of the parton distribution function. During the fourth year, the data set on rare observables will be complemented and in the fifth year, lighter ion systems (probably argon collisions) will be used to measure the energy-density dependence of the observables. On a longer term, the program will be driven by the physics results obtained previously. Among the possible options, we are considering running proton-proton at the same energy as lead-lead ($\sqrt{s} = 5.5\mathrm{TeV}$), perform a mass scan in proton-A, to map the mass dependence of the parton distribution function, and in A-A to map the energy-density dependence. As additional option, we plan to measure the energy dependance of lead-lead collisions to close the gap between RHIC ($\sqrt{s} = 200\mathrm{GeV}$) and LHC energies.

The ALICE collaboration counts at present about 1000 collaborators distributed in 80 institutes from 28 countries around the world. Since the previous LHC Symposium, new institutes have joined the collaboration, from South Africa, United States, Mexico and Germany. New participations (Brazil, Japan, Turkey, United States) are under discussion. Several US institutes have joined to submit a proposal to DOE for the construction of a large electromagnetic calorimeter [4] which will noticeably enhance the ALICE physics potential in the hard-process domain. Similarly, Japanese institutions have submitted to their funding agencies a project to participate in ALICE by contributing to the completion of the Transition Radiation Detector (TRD) and to the Photon Spectrometer (PHOS).

The ALICE experiment has been designed with the objective to measure most of the particles which emerge from heavy-ion collisions around mid-rapidity. The measurement includes the identification of particles and the accurate determination of their momentum. Long lived charged hadrons are identified through energy-loss and time-of-flight measurements and short lived hadrons through the identification of their decay products. Leptons are identified through the measurement of transition radiation, and photons through electromagnetic calorimetry. The momentum is obtained by tracking charged particles within a modest magnetic field ($B = 0.2 - 0.5\mathrm{T}$). Several detectors covering the central-rapidity domain ($|\eta| < 0.9$) cooperate to achieve this goal. They have been designed to cover a broad range of transverse-momentum, extending from very low momenta (¡ $100\mathrm{MeV}/c$) up to fairly high momenta ($\sim 100\mathrm{GeV}/c$). The ability to identify particles over such a broad spectrum makes ALICE unique in its exploration of soft and hard phenomena in heavy-ion and proton-proton collisions. In addition to the mid-rapidity tracking system, a few detectors are dedicated to the measurement of particular observables, such as quarkonia states, photons and high-momentum identified particles, or of the global properties of the collision. The gauntlet which ALICE has to take up is to perform such high-quality and broad measurements in an environment of extremely large particle densities, which could be as high as 8,000 particles per rapidity unit. This would amount to about 15,000 particles entering the acceptance ($|\eta| < 0.9$) of the ALICE detectors.

The ALICE collaboration is presently finalizing its Physics Performance Report (PPR). Several chapters have already been published [5] as internal notes, other are in the editing phase (*ALICE Detectors* and *ALICE Performance: Tracking and PID*) and the last one *(Probes andObservables)* is in preparation.

2 Status of detectors construction

The ALICE experiment will be set up in the P2 cavern of LHC inside the volume of the solenoid magnet inherited from the LEP L3-experiment.

After dismantling the L3 experiment, a thorough inspection of the magnet cooling system has been undertaken. After refurbishing the external circuits it will be possible to operate the magnet at its nominal field of 0.5T. This fulfills one of the requirements, by the ALICE tracking system, for high-resolution measurements of particles with high-transverse momentum. The field homogeneity needed for a robust tracking in the high-multiplicity environment has been obtained by reducing the diameter of the axial holes in the magnet doors. This operation consisted in adding some 200 tons of iron plugs. The achieved field homogeneity results in field variations, inside the volume of the tracking system, below 2% of the nominal value.

We can distinguish in ALICE central detectors with a large acceptance, which realize the tracking and identification of charged particles, central detectors with a limited acceptance, dedicated to the measurement of particular probes and the forward detectors.

2.1 Tracking system

The central detectors, which constitute the ALICE tracking system, and their services are supported by mechanical space-frame structures whose construction minimizes the amount of material shadowing the more external detectors. The space frames slide on rails to facilitate installation and maintenance. The tracking system consists of cylinders covering the pseudo-rapidity range $|\eta| < 0.9$ and full azimuth. Closest to the interaction point (4cm $\leq R \leq$ 44cm) six layers of Si detectors constitute the Internal Tracking System (ITS). It is followed (0.8m $\leq R \leq$ 2.8m) by the main tracking detector of ALICE, a Time Projection Chamber (TPC). Enveloping the TPC, a Transition Radiation Detector (TRD, 2.9m $\leq R \leq$ 3.7cm) and a Time-Of-Flight (TOF) detector (3.7m $\leq R \leq$ 4.0cm) complete the central system.

2.1.1 Inner Tracking System: ITS

The ITS, in stand alone mode, has the function of a low momentum spectrometer extending the tracking ability of ALICE down to transverse momenta below 100MeV/c. In addition, in cooperation with the other tracking detectors, the ITS will determine with high accuracy ($< 100\mu$m) the position of the primary vertex and of secondary vertexes for the identification of short-lived particles, such as hyperons, D and B mesons. At last but not at least, the ITS will significantly improve the momentum resolution of the ALICE tracking system. The first two layers will participate in the trigger by providing a fast hit-multiplicity measurement. To fulfill the ALICE requirements and to cope with the extremely high particle density expected (up to 90 particles/cm^2 in the first layer) in heavy-ion collisions, the ITS will consist of 3×2 layers of Si detectors of three different technologies, pixel, drift and strip detectors. The four innermost layers, pixel and drift, provide true two-dimensional localization of the traversing particles and the four outer ones, drift and strip, have analog readout which provides particle identification through energy-loss measurements in the $1/\beta^2$ region. A model of the carbon-fiber structure which supports the layers and the services has been produced to study the cabling layout, the cooling and thermal uniformity of the system and to elaborate an installation scenario of such a fragile device in the extremely encumbered central-region of ALICE.

Silicon Pixel Detectors: SPD. The two innermost layers of ITS consist of silicon pixel detectors which provide the adequate spatial resolution (12μm in the bending plane and 100μm along the beams axis) and the two-track resolution (100μm in the bending plane and 850μm along the beams axis) required in high-multiplicity environments. The elementary unit of the SPD, called a ladder, will be a 200μm thick Si sensor bump-bonded to five 150μm thick pixel chips. The pixel chip implements the preamplifier-shaper and discriminator functions for 8,192 independent $50 \times 425\mu\text{m}^2$ readout cells. It is designed in radiation-tolerant 0.25μm CMOS technology. Several ladders have been successfully bonded, with yields exceeding 99% (i.e. over 99% of the channels within every pixel chip are working), however only with thick components (200μm-sensors and 300μm-chips). Recently, just before the date of the Symposium, two thinned ladders, of final thicknesses, have been delivered and successfully tested. It now seems that the industrial process of bump bonding and thinning is under control and that the production can start in due time. The signals are taken out from the pixel-chips and transported to the readout electronics by a 3-layer flexible printed-circuit, wire bonded to the chips. The readout card (Multi Chip Module) implements three ASIC chips. These hold the reference levels for the pixel chips, perform the slow control, multiplex the outgoing data and

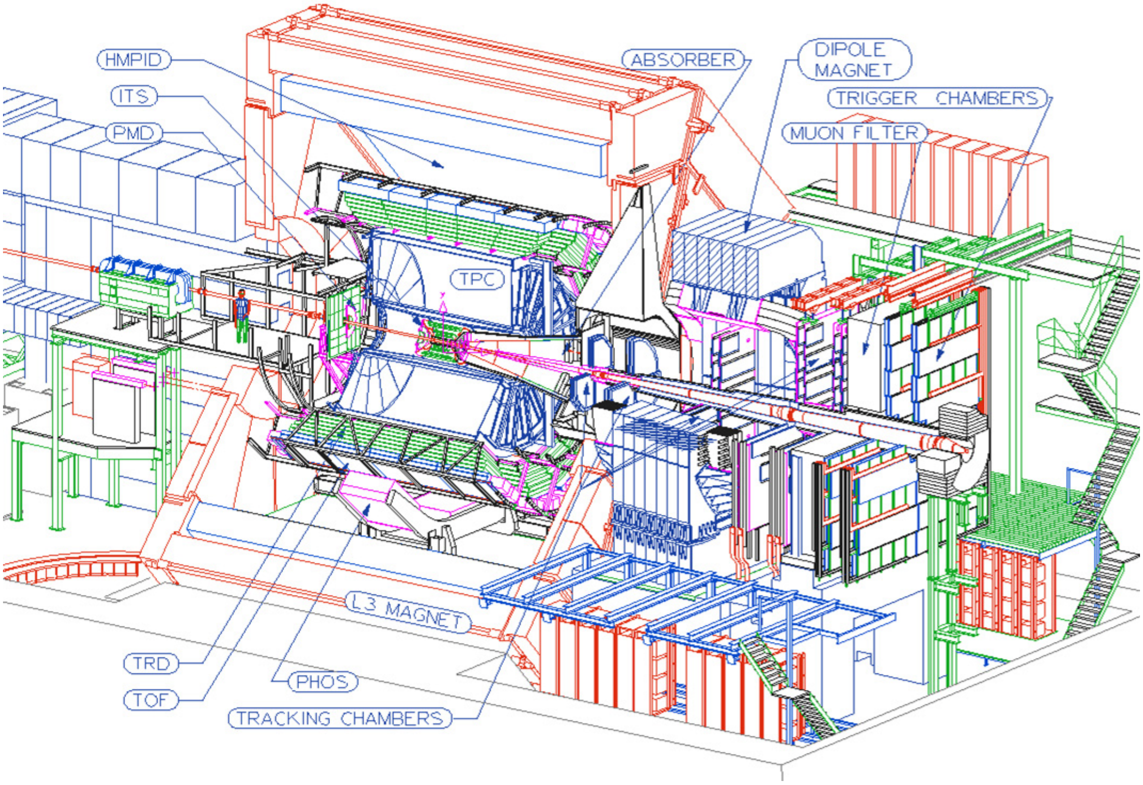

Fig. 1. The ALICE experiment

drive the laser diodes feeding the optical links. A whole chain from the laser to the optical link has been evaluated in test-beam. The resulting position resolution has been measured to be slightly better than the design values.

Silicon Drift Detector: SDD. Silicon drift detection modules, 300μm thick, assembled on 14, respectively 22, ladders holding six, respectively eight, modules each constitute the two intermediate layers of the ITS. The high-voltage divider, which shapes the drift and collection field, is integrated in the sensor as well as CMOS charge injectors used for monitoring the drift velocity. The homogeneity of the resistivity ($3\mathrm{k}\Omega \pm 8\%$) required for the sensor to achieve the desired position resolution ($40\mu\mathrm{m}$ in the bending plane) is obtained by using neutron-transmutation-doped high-resistivity n-type silicon material. The industrial production technology has been mastered and silicon modules are produced with a yield of about 50%. The two faces of the modules are independently biased by means of specially designed aluminum-polymide micro-cables: a transition cable ($\sim 130\mu$m thick) wire bonded to the detector and a thicker cable ($\sim 300\mu$m thick) bonded to the transition cable and connected to the high-voltage divider. This cable layout can hold up to 6kV. The readout-electronics design has been finalized and a prototype of the front-end readout unit has been tested in beam. The readout unit consisted of a hybrid circuit implementing four PASCAL chips (pre-amplification, analog storage and analog-to-digital conversion) followed by four AMBRA chips (buffering). The chips have been produced in radiation-tolerant, 0.25μm CMOS technology. After corrections (using the measured inhomogeneity map, and taking into account the non-linearity in the voltage divider, the diffusion widening and the temperature dependence of the drift velocity monitored with the on-detector charge injectors) resolutions better than 30μm have been achieved in both drift direction and along the anode axis.

Silicon Strip Detector: SSD. The two outermost layers of the ITS consist of 34 and 36 ladders each equipped with 23 and 26 double-sided silicon strip-modules. The ladder frame, the same as the one for the SDD, is a light-weight (15g) and stiff carbon-fiber triangular truss which rests on two conical frames positioned at both ends of the ITS cylinder. These conical frames also support the SDD ladders, the services for SDD and SSD and the silicon-rings of the forward multiplicity-detectors. The tape-automated-bonding technology, adapted for SDD and SSD, is used to link signals from the detector to the front-end electronics by means of flexible Al-micro-cables. The readout chips HAL25 (pre-amplification, shaping, multiplexing, analog output and control functions) twelve for every module, will be produced in radiation-tolerant, $0.25\mu\mathrm{m}$ CMOS technology. The production of these chips has been delayed because of yield problems. Test are currently underway with final silicon-modules TAB-bonded prototype HAL25-chips.

2.1.2 Time Projection Chamber: TPC

The Time Projection Chamber is the main tracking device of the ALICE experiment. The task assigned to the TPC is to provide the precise momentum measurement of all charged particles with momentum below 10GeV/c and, in collaboration with other tracking devices, good momentum measurement up to about 100GeV/c. In addition, energy-loss measurements will provide information for charged-particle identification. The goal is to achieve momentum resolution better than a few percent for particles with momenta below 5GeV/c and about 10% for 100GeV/c (when using combined other tracking detectors). The resolution on energy-loss measurement depends on the track multiplicity inside the TPC and varies from about 5% for $dN_{ch}/d\eta = 2,000$ to about 7% for $dN_{ch}/d\eta = 4,000$. Two-tracks resolution better than 5MeV/c in four-momentum space is required for correlation measurements of particle pairs with low relative momenta. These performances are confirmed by simulation and reconstruction using newly developed tracking algorithms. Efficiencies better than 95% can be achieved for good track reconstruction, independent of the particles momentum down to 100MeV/c (see the presentation by C. Blumme [1]).

The TPC consists of four 5m long cylindric vessels. Two field-cage vessels (inner and outer field cage) define the active drift-volume of the TPC , with radii of 0.9m and 2.5m. It is filled with a Ne(90)-CO_2(10) gas mixture. Two additional vessels (inner and outer containment vessels) provide a CO_2-filled volume to isolate the TPC high-voltage. In the center of the field-cage, a high voltage electrode biased to 100kV creates a drift field along the axis of the cylinder. The resulting drift-time is 88μs from the interaction point to the ends of the cylinder where the readout chambers are located. The readout chambers are supported by two end-plates and are segmented in 18 trapezoidal sectors, each covering 20° in azimuth. Each sector contains two readout chambers, a smaller one for the inner chambers (Inner ReadOut Chamber, IROC) and a larger one for the outer chambers (Outer ReadOut Chamber, OROC). All vessels are constructed out of composite material to keep the material budget to a minimum. The outermost vessels have been assembled and quality checks (mechanical tolerance, leak tests) have been successfully performed. The recently delivered inner field-cage presented serious gas leaks at the junction of the vessel and the aluminum flanges. As repairs are not possible, this vessel will be reconstructed. The inner containment vessel is presently under construction. The end plates and the support wheel for the central electrode have been fabricated and passed the mechanical tolerance checks. The fabrication of the central electrode realized by stretching three layers of mylar foils, glued together, has been validated. The construction of the readout chambers, multi-wire proportional chambers with cathode pad readout, is fairly well advanced: 65% of the inner chambers and 10% of the outer chambers are completed.

The functionalities of the readout chain are provided through a single front-end card (Front End Card, FEC). They include, for each channel, pre-amplification and shaping (PASA custom chip), 10-bit digitization and digital processing (tail cancellation, baseline restoration, data compression and events buffering). The two last functionalities have been combined in a single chip (ALice TPC ReadOut, ALTRO) to reduce the complexity of the assembly. The front-end electronics is linked to the DAQ system through a Readout Control Unit (RCU) which has been prototyped and for which the final design is in progress. The front-end card has been fully tested, the PASA chips are in production and the production of the ALTRO chips is completed. A complete readout chain including one IROC chamber, four FEC, i.e. 512 channels, has been tested with cosmic rays demonstrating, in particular, the excellent performance of the digital processing in the ALTRO chip. The measured noise level is 700e to be compared to the requested designed value of 1,000e.

2.2 Particle identification system

For many observables [1] particle identification capability is a necessity. The central tracking system provides pion/kaon/proton discrimination through energy-loss measurement in TPC and ITS. Furthermore, the vertex finding capability of the central tracking system provides the means to identify short-lived particles, such as hyperon, charmed and beauty mesons, through the identification of their hadronic decay. Additional particle identification capability is provided for a broad range of particle species and over a wide momentum range by an ensemble of complementary detectors which complete the particle identification of the central tracking system. The measurement of the time of flight (TOF) improves the $\pi/K/p$ discrimination power. High-transverse momentum (p_T >1 GeV/c) electrons are identified (TRD) and efficiently discriminated against charge pions through the measurement of X-rays emitted in a transition radiation detector. Cerenkov ring-imaging technique (HMPID), applied over a limited solid angle, improves the hadron discrimination at higher momenta, π/K up to 3GeV/c and K/p up to 5GeV/c. Photons are identified in a small solid angle by an electromagnetic spectrometer (PHOS) combining electromagnetic calorimetry and charged particle vetoing. Muons are detected and identified in the forward direction by a dedicated spectrometer.

2.2.1 Transition Radiation Detector: TRD

High momentum electrons are identified and discriminated against pions by complementing the tracking information of TPC and ITS with the measurement of the transition radiation generated by ultra-relativistic electrons crossing heterogeneous material. The Transition Radiation Detector will act as an electron spectrometer to identify charm and beauty mesons through their semileptonic decay and charmonium- and bottomium-states through their e^+e^- decay channel. Furthermore, the fast tracking capability of the TRD electronics will allow to trigger on high-momentum electron- and hadron-events, the latter being of interest for the jet-physics programme. The elementary detection system of the TRD consists of a radiator foil (polypropylene fibers sandwiched between glass-fiber enforced Rohacell foils) followed by a time expansion chamber with cathode-pad readout and filled with a heavy-gas mixture (Xe(90)/CO_2(10)). Six such systems are stacked to form a module and five modules are assembled in 7m long super-modules to cover the same rapidity range as the TPC. 108 super-modules are needed for full azimuthal coverage. The operation principle has been tested in beam by stacking a full size prototype of one of the chambers and five smaller test chambers connected to the prototype of the readout electronics. The results indicate that, for an electron detection efficiency of 90%, the pion rejection factorizes with the number of chambers leading to the requested overall rejection factor of 100. This value remains approximately constant over the measured momentum range between 1 and 6GeV/c.

2.2.2 Time-Of-Flight: TOF

The Time Of Flight detector constitutes the outer most shell of the central barrel in the ALICE experiment. Combined with the tracking information (charge, momentum and energy loss) collected by ITS and TPC, the measurement of the time-of-flight completes the charged hadrons identification. It will significantly improve the performance to identify pions, kaons and protons in the intermediate momentum range, between 0.2GeV/c and 2.5GeV/c. To achieve this goal, a time resolution better than 100ps is required. Such excellent time resolution can be achieved using Multi-gap Resistive-Plate Chambers (MRPC) technology. The choice for TOF was to stack two layers of five thin-gap parallel-plate chambers each. The stack of chambers is assembled in strips of various lengths (1.17, 1.57, 1.77m), mounted on a barrel with 3.7m radius. Several tens of such strips have been constructed and tested in beam. The measured average time resolution of about 60ps is well within the requirements. For a detailed description of the detector layout and of the operation mode of the MRPC, see [6].

2.2.3 High Momentum Particle Identification Detector: HMPID

The High-Momentum Particle Identification Detector is a dedicated spectrometer for the detection and identification of charged hadrons extending the resolving power of the combined ITS, TPC and TOF towards higher transverse momenta, 3GeV/c for π/K discrimination and 5GeV/c for K/p discrimination (for a 3σ limit). The detection system exploits Cerenkov ring-imaging technique with a liquid C_6F_{14} radiator and a multi-wire proportional chamber with pad readout UV detector. The photocathode consists of a thin layer of CsI evaporated on the pad plane. HMPID will cover a limited solid angle ($-0.6 < \eta < 0.6$, 57.61° azimuthal coverage at 5m from the interaction point). The detector has been recently relocated at a two o'clock position to free space for a future large-coverage electromagnetic calorimeter [4]. It has a three-fold segmentation in rapidity and azimuth, but only seven modules will be constructed, providing a total active area of 10m^2. A small (2/3) prototype of one module was operational during the first heavy-ion an proton runs at RHIC and has produced physics data. It has now been returned to CERN. All the elements for the construction of the seven modules and most of the components needed for the readout chains have already been procured. The construction of the modules is in progress. The deposition of the CsI layer on the photo-cathode will however be delayed as late as possible to prevent deterioration of the performance of CsI, due to aging.

2.2.4 Photon Spectrometer: PHOS

The Photon Spectrometer is the outermost central detector, located at 5m from the interaction point and covering a limited solid angle ($-0.12 < \eta < 0.12$, 100° azimuthal). To measure photons with high resolution (about 2% for $E_\gamma > 2$GeV) and discriminate against charged hadrons, a highly segmented $PbWO_4$ calorimeter is associated with a multi-wire proportional chamber enabling charged particle vetoing. The calorimeter will be stabilized at a temperature of -25°C to enhance the light output of the $PbWO_4$ crystals. The light readout is performed by low-noise APDs. The segmentation of the calorimeter provides the position resolution required to identify neutral mesons through the measurement of their two-photon decay channel. Additional particle identification is provided by time-of-flight, shower-topology and isolation measurements, in particular for neutron and anti-neutron discrimination and direct photon identification. The spectra of identified direct photons and neutral pions will be measured over a broad momentum range from about 1GeV/c up to about 80GeV/c. Direct photons and neutral pions will be identified on an event-by-event basis in the high-momentum range from 30 to 100GeV/c making PHOS a particularly attractive detector for jet physics. So far, the North Crystals Company at Apatity (Russia) has delivered 3,000 crystals which meet the requirements (out of the 17,920 crystals needed to equip the 5 modules with a total area of 8m^2 , planned for PHOS). The production rate is 300 crystals per month. The design of the readout electronics, including a high transverse-momentum photon trigger which will enter the general ALICE trigger system, is presently in progress. It will make use of the ALTRO chip, developed for the TPC readout chain, for digitization and digital processing. In beam tests of a 8×8 matrix of the calorimeter detectors demonstrated the validity of the design by meeting the required performances in energy and position resolution.

2.3 Forward muon spectrometer

The forward muon spectrometer is a complex detector system, dedicated to the detection and identification of muon pairs. Its purpose is to perform high-resolution mass-spectroscopy of charmonium and bottomium states. The goal is to achieve a resolution of 100MeV/c^2 at the Υ mass. The spectrometer, located in the forward rapidity region on one side of the ALICE experiment, consists of hadron absorbers (11 absorption lengths) shielding the spectrometer from the interaction point and from the beam pipe, a 3Tm dipole magnet, a set of five tracking stations of frame-less multi-wire proportional chambers, two trigger stations of resistive-plate chambers preceded by a 1m thick iron wall. Details on the construction status and performances of the elements of the spectrometer can be found in [7].

2.4 Forward detectors

Various detectors, with well defined objectives (triggering, event selection, global properties measurement), will be located at large rapidity on both sides of the interaction point.

The Zero Degree Calorimeters, ZDC, consist of four small calorimeters located 110m away from the interaction point inside the LHC tunnel. They are made of an assembly of tantalum or brass with embedded quartz fibers. Proton spectators deflected by the first LHC dipole will be detected by the brass-ZDC set and neutron spectator by the tantalum-ZDC set. The ZDC will provide a measure of the impact parameter and trigger information. One of these calorimeters has been constructed.

The Photon Multiplicity Detector, PMD, consists of two ensembles of honeycomb-cell proportional chambers sandwiching a passive Pb converter. It is located at 3.6m from the interaction point on the side opposite to the muon spectrometer. It will measure the relative rate of photons and charged particles to search for non-statistical event-by-event fluctuations which could sign e.g. the formation of a disoriented chiral condensate. The technique has been validated with a prototype installed at RHIC with the STAR experiment.

The Forward Multiplicity Detector, FMD, consists of five disks of silicon pad detectors, two are on the muon spectrometer side and three on the opposite side. Together with the ITS, the FMD provides a complete rapidity coverage from -5.1 to 3.4 for the detection of charged particles. The design of the detectors, mechanical supports and readout electronics is fairly well advanced and the Technical Design Report, including also the V0 and T0 detectors is in preparation.

The T0 detector will provide the start signal for time-of-flight measurements and a trigger signal at level L0 with a resolution better than 50ps. It consists of two arrays of twelve Cerenkov detectors each, located on both sides of the interaction point, at 70cm on the muon spectrometer side and at 350cm on the opposite side.

The V0 detector will act as the main interaction trigger and will be used to locate the interaction vertex online. It covers the rapidity range between -5.1 and -2.8 and between 3.8 and 1.7. It consists of two arrays of scintillators, assembled as disks, with embedded wavelength shifting fibers, located at 90cm (muon side) and 350cm (opposite side) from the interaction point. Coincidence between arrays on both sides will provide efficient means to identify beam-gas interactions.

3 Status of control and computing

3.1 Detector and experiment controls system: DCS and ECS

A ALICE Control Coordination team (ACC) has been created with the task of coordinating the design and implementation of the Detector Controls System (DCS) of ALICE. The DCS will provide an operator in the ALICE control room with full control of the entire experiment and enable him to operate and supervise it during all modes of operation. It will allow the various detector and service groups to assume full control of their equipment and enable them to work independently and autonomously whenever required, e.g. during installation, commissioning and maintenance phases.

During the initial project phase, much effort has been devoted to define the control requirements. This has resulted in user requirement documents which have been drafted for each detector and for all the various infrastructure services. The software and hardware architecture of DCS has been defined. The basic system tools and components, such as the PVSS SCADA system, the OPC and DIM communications protocols, have been evaluated and selected. The prototyping activity has started. Control prototypes for various sub-systems, such as high- and low-voltage power supplies, have been developed by detector groups and the ACC team. The first tests with detector equipment have been performed by the HMPID detector group. Similar tests are, at present, being performed by other detector groups and with other devices to control.

An Experimental Control System (ECS) layer, through which the online systems Trigger, DAQ and DCS will be synchronized, has been defined and a first prototype has been developed. First tests with detector equipment have been performed by the HMPID detector group.

3.2 Trigger, DAQ, and HLT

The final design of the trigger system includes one pre-trigger and three trigger levels (L0, L1, L2). The pre-trigger from T0 and V0 provides, in less than 100ns, a wakeup signal for the TRD front-end electronics. L0 (1.2μs) and L1 (6.5μs) levels provide the gating signal for fast detectors and the L2 (¡100μs) level, which includes a past-future protection scheme, triggers the readout of the slow TPC. The design of the hardware for the trigger system, including the Central Trigger Processor and the

Local Trigger Unit for distributing the trigger decision, is basically completed.

Data selected by the trigger are transfered in parallel from the detectors to the DAQ system over optical links (Detector Data Link, or DDL) via PCI adapters (the Read Out Receiver Card, RORC) to a farm of 300 individual computers, the Local Data Concentrators (LDC). The transfer is initiated by the L2 trigger. The different data fragments, corresponding to the information from one event, are checked for data integrity, processed and assembled into sub-events in the LDC. Sub-events are sent over a network for the event building to one of the 40 Global Data Collector computers (GDC), which can process up to 40 different events in parallel. Events formatted as ROOT objects are finally sent to the storage network. The Data Acquisition and Test Environment (DATE) is the software framework of the ALICE DAQ which provides the various functionalities, process synchronization and control needed for the data flow. The DAQ system flexibility and scalability is tested in Data Challenges of increasing complexity. A main issue is the 1.25GByte/s bandwidth to mass storage required for data taking during heavy-ion runs. Several large-scale high-throughput distributed computing exercises are regularly performed. In a recent data challenge, DATE has demonstrated aggregate performances of more than 1GByte/s. The data throughput to the mass storage has reached a sustained transfer rate of 300MByte/s, exceeding the foreseen milestone value. This bandwidth is already sufficient for data taking in proton runs and can be extrapolated to the value required for the ion runs assuming a modest evolution of technology. Prototypes of RORC which implements the optical interface for the DDL and the PCI interface to the LDC have been constructed. The design of this key card is, however, still evolving.

A software trigger (the High Level Trigger or HLT) for rare events, whose identification requires partial or full reconstruction of the events, will be provided to the DAQ data flow at the LDC level by a dedicated computer farm associated with FPGA co-processors embarked on PCI cards. The final design for the interface between DAQ and HLT systems is still under discussion.

3.3 Offline

The ALICE offline-software framework, AliRoot, has been based on the ROOT package to take advantage of a number of important existing elements such as a complete set of containers, integrated I/O with automatic schema evolution, C++ as a scripting language, a large set of utility functions (math, random numbers, multi-parametric fit and minimization), documentation tool, a complete data analysis environment, and graphical user interface toolkit. AliRoot performs all the tasks for event simulation, reconstruction and data analysis. It has recently evolved to extend its functionalities. A virtual interface, the Virtual Monte-Carlo, to particle-transport packages has been developed to enable switching at run time between packages. At present the interfaces for GEANT3, GEANT4 and FLUKA have been implemented. The new ROOT geometry package, the geometry modeler, has been adopted. It is a tool designed for building, browsing, tracking and visualizing a detector geometry. The package defines an interface to feed any geometrical query (e.g., “where am I”, “which is the next boundary to cross”) posted by external applications to the geometry. These features enable using the same geometry for several purposes such as simulation, reconstruction, visualization and event display.

AliEn (for Alice Environment) is a major new development in the ALICE offline software. AliEn is a distributed computing framework which extends the use of AliRoot in an environment of distributed computing resources by providing a Grid interface for ALICE users. AliEn is built using the latest INTERNET standards for information exchange and authentication and common Open Source components (90% of the code). AliEn provides a virtual file catalog which allows transparent access to distributed data sets. It also provides an insulation layer between different Grid implementations which has been tested with the EDG testbed. AliEn is now fully operational for world wide distributed simulation and reconstruction tasks. 32 sites, among which 5 provide mass storage, mainly in Europe and USA, have been configured. Over 22,000 events have been produced and reconstructed (jobs of 12 hours/event), most of them in a two months long data challenge (up to 450 concurrent jobs), with a failure rate below 10% and requiring only one operator part time. Developments are presently underway to provide functionalities for concurrent distributed analysis tasks.

4 Conclusion

ALICE has entered a challenging period during which major systems have or are about to enter series production and which ends the equally challenging period of research and development. In the former L3 cavern, the large solenoid magnet has been refurbished and is ready for the installation of the mechanical infrastructure. A detailed installation and commissioning plan, endorsed by the LHC Committee, has been established so that ALICE will be complete and ready in time to measure the first pp collisions in April 2007 and to take data in an early heavy-ion pilot run. ALICE has developed a framework which provides a complete implementation of a light-weighted Grid which was the key element to produce the huge number of simulated events needed for the preparation of the Physics Performance Report. In parallel the ALICE collaboration is structuring its heavy-ion physics programme, based in part on the exciting results obtained so far at RHIC, and complemented by a unique proton-proton physics program.

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